

Alexander Barash ° and Zippora Danin °

CONTRIBUTION TO THE KNOWLEDGE OF MOLLUSCA
IN THE BARDAWIL LAGOON °°

Summary

The hypersaline Bardawil Lagoon, near the Suez Canal, is linked through openings to the Mediterranean Sea. Only six species of Mollusca are resident in the Lagoon: *Pirenella conica* (BLAINVILLE), *Diala varia* A. ADAMS [= *D. semistriata* (PHILIPPI)], *Cerithium scabridum* PHILIPPI, *Brachidontes variabilis* (KRAUSS), *Cerastoderma glaucum* (BRUGUIÈRE) and *Mactra olorina* PHILIPPI. The scant representation of the Indo-Pacific species, to be found in the Mediterranean, in the hypersaline body of water is discussed.

Riassunto

La laguna di Bardawil (Nord Sinai) è separata dal Mediterraneo da una stretta barriera (in media 500 m di larghezza) di sabbia. Lunga circa 90 km e larga sino a un massimo di 22 km, comunica con il Mediterraneo solo attraverso tre esigue aperture, una naturale all'estremità orientale e due artificiali (Boaz I e Boaz II, si veda Map. 2). Il ricambio idrico scarso, il clima arido, la profondità minima delle acque nella laguna fanno sì che questa, sottoposta a un'evaporazione intensiva, raggiunga valori di salinità molto elevati (da un minimo di 40‰ nei pressi dei canali artificiali sino a un massimo di 70‰ nel punto più lontano da questi). In tali condizioni possono vivere solo molluschi decisamente eurialini ed in effetti solo le seguenti specie sono state raccolte viventi: *Pirenella conica* (BLAINVILLE), *Diala varia* A. ADAMS, *Cerithium scabridum* PH., *Brachidontes variabilis* (KRAUSS), *Cerastoderma glaucum* (BRUGUIÈRE) e *Mactra olorina* PH. Nonostante la relativa vicinanza del canale di Suez, da cui sono sicuramente penetrate nel Mediterraneo oltre una trentina di specie, le

° Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv, Israel.

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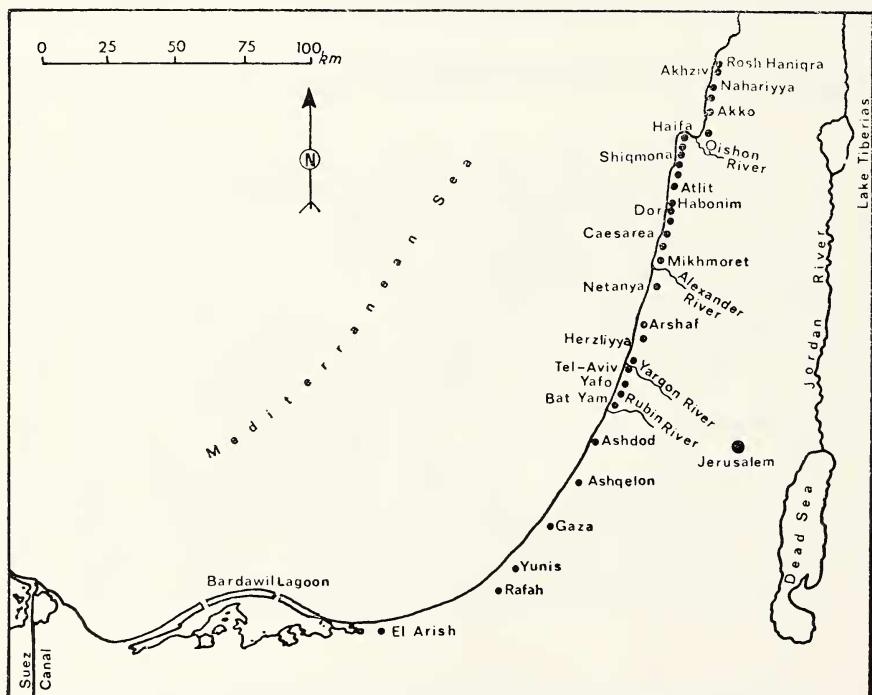
condizioni particolari della laguna rendono impossibile la sopravvivenza per tutte quelle specie, come appunto le sei citate, che non presentino peculiari doti di resistenza. Sono state invece raccolte nella laguna numerose conchiglie appartenenti a 56 specie diverse, probabilmente trascinate nella laguna stessa dai marosi che superarono l'antistante litorale.

Introduction

The Bardawil Lagoon (Sirbonian Lagoon) is situated along the Mediterranean coast (Map 1) of Northern Sinai. The area of the Lagoon is approximately 650 km², with the maximum length from east to west being about 90 km and the maximum width about 22 km.

The Lagoon is separated from the Mediterranean Sea by a long, narrow sand bar, approximately 500 m wide. The bar is low for most of its length, reaching a maximum height of about 50 m in the middle section at Mount Cassius (Kalas).

The Lagoon is linked to the Mediterranean Sea by three openings, two of them artificial canals, Boaz I and Boaz II, while the most eastern opening, Zarnich, is a natural one. The two artificial canals cut in the sand bar are the most essential ones for the exchange of water between the Lagoon and the open sea (BEN TUVIA and HERMAN, 1972).



Map 1 - Israel and Northern Sinai

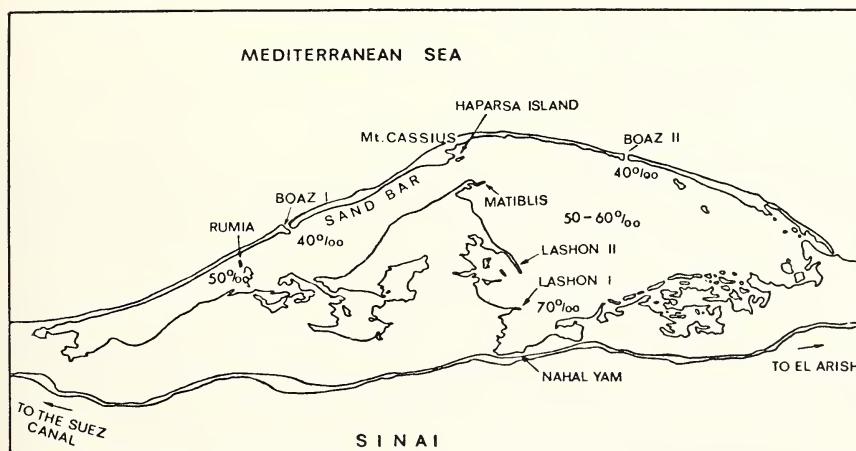
The Lagoon is very shallow; the depth ranges from a few centimeters near the shore to 0.5 - 1.5 m in most places, and reaches a maximum depth of about 3 m (LEVY, 1974; BEN TUVIA, 1979). The shallowness of the Lagoon facilitates the penetration of light to the plants on the bottom.

From a depth of about 40 cm and downwards the monocotyledonous plant *Ruppia cirrhosa* forms a dense cover on the bottom (LIPKIN, 1977), overlaid with a thick layer of some filamentous algae, mostly *Cladophora* spp. Large amounts of detritus and debris collect among the roots and in between the leaves of *Ruppia*.

Sand is the predominant sediment on the bottom in the areas near the shore and near the bar. The deepest parts of the Lagoon are covered with clay as well as sand.

Bardawil Lagoon is situated in an arid semidesert area. High surface water temperatures prevail in the Lagoon during most months of the year (over 20°C). The highest temperature measured in summer 1973 was 34°C, the lowest winter temperature was 10°C (BEN TUVIA, 1979).

The Lagoon is noted for its high rate of water evaporation. Salinity in the almost closed Lagoon is much higher than in the adjacent open sea. The lowest salinity ca. 40‰ (values rounded off), was registered near Boaz I and Boaz II (Map 2). In the more central localities salinities are mostly 50-60‰ and the highest salinity — 70‰ — was measured near Nahal Yam which is the farthest point from the openings (see POR, 1978: 37).



Map 2 - Bardawil Lagoon

Hypersalinity is the most distinguishing ecological factor in the Lagoon, probably governing the composition of the fauna there. Salt concentration in the Lagoon is not evenly distributed, being considerably affected by the influx of sea water through the openings leading to the Mediterranean. The salinity decreases in winter and increases in summer. In winter the salinity also drops during storms, when waves wash over low portions of the bar.

During the years 1967-1979 the fauna of the Lagoon was explored mainly by Prof. A. Ben Tuvia, of the Hebrew University, Jerusalem. The samples of Mollusca collected in various localities in the Lagoon (Boaz I, Boaz II, Haparsa Is., Matiblis, Lashon I, Lashon II, Rumia, Nahal Yam [Map 2]), were placed at our disposal for examination. The molluscs collected in the Lagoon by Mr. H.K. Mienis and by other workers from the Universities of Jerusalem and Tel Aviv were also studied.

The following species of Mollusca may be considered as indigenous inhabitants of the Bardawil Lagoon:

GASTROPODA

Pirenella conica (BLAINVILLE, 1826) = *Pirenella cailliaudi* (POTIEZ and MICHAUD, 1838)

Diala varia A. ADAMS, 1861 = *Diala semistriata* (PHILIPPI, 1849)

Cerithium scabridum PHILIPPI, 1849

BIVALVIA

Brachidontes variabilis (KRAUSS, 1848)

Cerastoderma glaucum (BRUGUIÈRE, 1789)

Mactra olorina PHILIPPI, 1846

The distinction between specimens containing the animal and those found as dead shells is essential for biological and ecological research. Locating soft parts of the body within the shell is often very difficult. It seems appropriate to use in this paper the term specimen (abbreviated - spm) for the individuals collected.

Over 15,000 specimens collected in the Lagoon were examined: *Pirenella conica* (= *P. cailliaudi*) - 10,532 spm.; *Diala varia* - 139; *Cerithium scabridum* - 1,680; *Brachidontes variabilis* - 305; *Cerastoderma glaucum* - 1,883 and *Mactra olorina* - 735 spm.

The categories of frequency used accordingly for these species are as follows: abundant, very common, common, not uncommon. These are, however, of rather general value. Statistical indicators, based on a larger amount of material, are needed for a more precise designation of frequencies.

Specimens referred to in the present report are kept mostly in the collection of Tel Aviv University. The following initials are used for samples collected by: Prof. Ben Tuvia - BFS; Tel Aviv University - NS; the Sea Fisheries Research Station - SFRS; the Hebrew University, Jerusalem - HUJ and SLML. (The registration numbers of some samples were not indicated).

Materials and Distribution

GASTROPODA Family Potamididae

Genus *Pirenella* GRAY, 1847

Pirenella conica (BLAINVILLE, 1826) (Table I, Fig. 1) - Height 12,5 mm (average).

Cerithium conicum BLAINVILLE, 1826; JOUSSEAUME, 1930 : 294

Potamides conica (BLAINVILLE); MOAZZO, 1939 : 176

Pirenella conica (BLAINVILLE); PALLARY, 1912 : 111-113, pl. XV, fig. 52

Pirenella cailliaudi (POTIEZ and MICHAUD, 1838); id.

Cerithium cailliaudi POTIEZ and MICHAUD, 1838; ISSEL, 1869 : 150

Potamides cailliaudi (POTIEZ and MICHAUD); STURANY, 1903 : 54 (262)

Bardawil Lagoon Records: BARASH and DANIN, 1971 : 98; 1973 : 307; 1977 : 89; POR, 1971 b : 247; 1978 : 38.

Material:

Boaz I, 2.II.1970, 320 spm. (BFS); 11.VI.1974, 42 spm. (BFS 242); 3.IX.1974, 67 spm. (BFS 293, BFS 294). *Boaz II*, 12.VI.1974, 23 spm. (BFS 245); 5.VIII.1974, 8 spm. (BFS 275); 11 spm. (BFS 276); 15.IX.1974, 10 spm. (BFS 310); 30.IX.1976, 355 spm. (HUJ). *Haparsa* Is., 11.VI.1974, 375 spm. (BFS 239); 12.VI.1974, 37 spm. (BFS 240); 10.VII.1974, 31 spm. (BFS 265); 15.IX.1974, 10 spm. (BFS 303). *Matiblis*, 2.VII.1974, 3 spm. (BFS 259); 3.VII.1974, 34 spm. (BFS 263); 3.VIII.1974, 12 spm. (BFS 254); 6.VIII.1974, 15 spm. (BFS 279). *Lashon I*, 9.IX.1969, 525 spm. (NS 16783, NS 16785); 2.VI.1974, 15 spm. (BFS 247); 11.VI.1974, 37 spm. (BFS 244); 16.VII.1974, 39 spm. (BFS 267, BFS 269); 6.VIII.1974, 126 spm. (BFS 283, BFS 284); 21.VIII.1974, 314 spm. (BFS 291, BFS 292); 3.IX.1974, 90 spm. (BFS 294, BFS 302); 15.IX.1974, 10 spm. (BFS 310). *Lashon II*, 11.VI.1974, 90 spm. (BFS 243); 3.IX.1974, 38 spm. (BFS 294); 15.IX.1974, 47 spm. (BFS 307); 11.X.1974, 12 spm. (BFS 300). *Rumia*, 15.VII.1974, 13 spm. (BFS 272); 16.VIII.1974, 5 spm. (BFS 271). *Nahal Yam*, 9.I.1974, 2705 spm. (HUJ), 2.IV.1974, 4347 spm. (NS 16784, NS 16786). *Bardawil Lagoon* (localities not indicated), 7.II.1956, 5 spm. (HUJ 20.400); 1974, 421 spm. (HUJ).

Frequency:

Abundant, dominant in the most shallow belt of the lagoon near the waters' edge (POR, 1971 b : 247).

Distribution:

- 1) *Mediterranean coast of Israel*: Rafah, Ashdod, Bat Yam, Tel Barukh, Mikhmoret, Maagan Mikhael, Dor, Atlit, Carmel Beach, Shiqmona, Habotrim, Bat Gallim, Haifa Bay, Qishon, Qiryat Yam, Akko, Shaveh-Ziyyon (see Map 1).
- 2) *Suez Canal*: Port Said, Lake Manzala, Lake Timsah, the Bitter Lakes and the Canal proper (MOAZZO, 1939 : 176, 278; BARASH and DANIN, 1973 : 354).
- 3) *Further Distribution*: Eastern Mediterranean: Egypt (PALLARY, 1912 : 111-113), Lebanon - Syria (GRUVEL and MOAZZO, 1931 : 448; PALLARY, 1938 : 35); Western Mediterranean: Ionian Sea (PARENZAN, 1961 : 65); Adriatic Sea, Sicily, Malta, West Italy, Sardinia, South France, Algeria, Tunisia (CARUS, 1893 : 360). East Spain (HIDALGO, 1917 : 559). Indo Pacific: Gulfs of Suez and Aqaba, Red Sea (STURANY, 1903 : 70), Aden (SMITH, 1891 : 391), Persian Gulf (SMYTHE, 1979 : 65); India - Bombay (TOMLIN, 1927 : 315), Madagascar (DAUTZENBERG, 1929 : 490).

Notes

The taxonomy of the *Pirenella* species in the Near East is still insufficiently elucidated. Three species were distinguished in this area: *Pirenella conica* (BLAINVILLE), *Pirenella cailliaudi* (POTIEZ and MICHAUD) and *P. cinerascens* (PALLARY, 1855), (PALLARY, 1912 : 111-113; NORDSIECK, 1968 : 67, 68). According to JOSSEAU, (1930 : 294) *Pirenella cinerascens* is identical with *P. cailliaudi*.

The two species of *Pirenella* commonly mentioned in the malacological literature of the area are *P. conica*, considered as a Mediterranean species, and *P. cailliaudi*, considered as from the Indo Pacific. SMITH (1891 : 391) stated that « nearly all the Suez specimens (of *Pirenella cailliaudi*) ... have two distinct rows of granules on the upper whorls, whereas in Mediterranean specimens (of *P. conica*) there are mostly three or more rows and in these the granules are smaller than in the Red Sea specimens ».

TOMLIN (1927 : 296) noted, however, that « after examining a great many examples collected in Lake Manzala and Kabret I find it quite impossible to discriminate between *P. conica* and *P. cailliaudi*. The gatherings of *Pirenella* specimens in this site include every possible variation of sculpture from spiral rows of granules down to forms with the spiral ridges obsolete and without any granulations at all ».

The authors of this paper arrived at a similar conclusion after examining numerous specimens of *Pirenella* collected in the Bardawil Lagoon, as did TARASCHEWSKI (1979) in his study in the Lagoon of Shura el Manquata (Gulf of Aqaba).

There are indeed numerous intermediate variants between the specimens which were considered as typical for *P. conica* and those for *P. cailliaudi*; in size, convexity of the whorls, colouration and in particular in the sculpture of the shell. The integration of the different variants of *Pirenella* into one species — *Pirenella conica* — thus seems to be appropriate.

« A study of electrophoretic patterns or enzymes can contribute to the solution of the question of whether only one species of *Pirenella* or more are present in the area treated in this paper (AVISE, 1974). In general, individuals belonging to different species should contain different alleles, at least in some of the loci investigated. Seventeen enzyme loci were studied in 3 samples of *Pirenella*: Dahab (Gulf of Elat) - 27 specimens; Mangrove area, Nabq (Gulf of Elat) - 30 specimens; Bardawil (Mediterranean) - 56 specimens.

Three enzymes proved to be monomorphic for the same allele in all 3 samples. The other 14 enzymes were polymorphic, but the differences between the samples were always quantitative, based on differences in the frequencies of the same patterns, which were found in all 3 samples. These results support the premise that all specimens from the different populations belong to one species » (Personal communication, Dr. U. RITA, Hebrew University Jerusalem).

It has been argued that specimens of *P. cailliaudi* found in the Mediterranean arrived in this area by way of the Suez Canal and should, therefore, be considered as immigrants into the Mediterranean (HAAS, 1948; BARASH and DANIN, 1973; GHISOTTI, 1974). However, TILLIER and BAVAY (1905) reported only *P. conica* from the Suez Canal and did not mention *P. cailliaudi* at all. TOMLIN (1927) also recorded only *P. conica* from the Suez Canal, because he found it impossible to distinguish between

this species and *P. cailliaudi*. Moreover, JOUSSEAUME (1930) stated that *P. conica* and *P. cailliaudi* are the same species under different names.

TOMLIN (1927 : 296, 319) maintains therefore that *P. conica* is a species common to both seas (Mediterranean and Red Sea) which may have entered the Suez Canal from either end.

Family Cerithiidae

Genus *Cerithium* BRUGUIERE, 1792

Cerithium scabridum PHILIPPI, 1849; JOUSSEAUME, 1930 : 279 (Table I, Fig. 2) - Height 18 mm (average).

Bardawil Lagoon Records: BARASH and DANIN, 1973 : 309; 1977 : 93; POR, 1978 : 38.

Material:

Boaz I, 2.II.1970, 378 spm. (BFS); 11.VI.1974, 38 spm. (BFS 242); 2.VII.1974, 3 spm. (BFS 252); 3.IX.1974, 14 spm. (BFS 294). *Boaz* II, 12.VI.1974, 6 spm. (BFS 246); 10.VII.1974, 11 spm. (BFS 275); 30.XI.1976, beach drift, over 100 spm. (HÜJ). *Haparsa Is.*, 1.IV.1974, 232 spm. (BFS); 15.IV.1974, 32 spm. (BFS 304); 11.VI.1974, 68 spm. (BFS 239); 12.VI.1974, 41 spm. (BFS 240); 10.VII.1974, 2 spm. (BFS 265); 15.IX.1974, 16 spm. (BFS 303); 12.XI.1974, 8 spm. (HÜJ); 17.XII.1974, 1 spm. (HÜJ). *Matiblis*, 2.VII.1974, 30 spm. (BFS 253); 3.VII.1974, 20 spm. (BFS 264); 16.VII.1974, 84 spm. (BFS 263); 3.VIII.1974, 80 spm. (BFS 254); 6.VIII.1974, 6 spm. (BFS 279); 9.II.1977, beach drift, 10 spm. (HÜJ). *Lashon* I, 11.VI.1974, 7 spm. (BFS 244); 6.VIII.1974, 7 spm. (BFS 283); 21.VIII.1974, 2 spm. (BFS 291); 15.IX.1974, 2 spm. (BFS 310). *Lashon* II, 2.IV.1974, 432 spm. (BFS); 11.VI.1974, 8 spm. (BFS 243). *Rumia*, 2.VII.1974, 10 spm. (BFS 249); 5.VIII.1974, 13 spm. (BFS 272); 16.VIII.1974, 8 spm. (BFS 271). *Bardawil Lagoon*, (localities not indicated), 25.XI.1974, 9 spm. (HÜJ); 1974, beach drift, 35 spm. (HÜJ); 1976, beach drift, 12 spm. (HÜJ).

Frequency:

Very common.

Distribution:

1) Mediterranean coast of Sinai and Israel: Along the coasts from Yunis to Akhziv.

2) Suez Canal: Port Said, Lake Timsah, Great and Little Bitter Lakes and along the Canal proper (MOAZZO, 1939 : 173, 268); BARASH and DANIN (1973 : 354).

3) Further Distribution: Indo Pacific: Gulf of Suez (STURANY 1903 : 70); Gulf of Aqaba (POR, DOR, AMIR, 1977 : 306); Red Sea (JOUSSEAUME, 1930 : 279); Gulf of Aden (SHOPLAND, 1902 : 175); Mauritius (VIADER, 1937 : 42); Persian Gulf (BIGGS, 1958 : 273). East Indies - Gulf of Manaar (SATYAMURTI, 1952 : 86). Eastern Mediterranean: Egypt (PALLARY, 1912 : 110); Lebanon-Syria (PALLARY, 1938 : 34). Western Mediterranean: Sicily (BARASH and DANIN, 1977 : 93, P. PIANI, 1979).

Family Dialidae (Cerithiidae, part)

Genus *Diala* A. ADAMS, 1861

Diala varia A. ADAMS, 1861 (Table I, Fig. 3) - Height 3 mm (average).

Diala varia A. ADAMS, 1861; TRYON, 1887 : 282

Diala semistriata (PHILIPPI, 1849); BARASH and DANIN, 1977 : 91, fig. 7

Rissoa semistriata PHILIPPI, 1849; DAUTZENBERG, 1929 : 293 (499)

Alaba semistriata (PHILIPPI) id.

Syrnola semistriata (PHILIPPI) id.

Litiopa semistriata (PHILIPPI) id.

Bardawil Lagoon Records: MIENIS, 1976 : 30; BARASH and DANIN, 1977 : 91.

Material:

Boaz I, 2.VII.1970, 3 spm. (BFS). *Boaz* II, 30.XI.1976, 1 spm. (HUJ). *Lashon* I, 2.XI.1970, 84 spm. (NS 16787). *Matiblis*, 9.II.1977, 12 spm. (HUJ). *Nahal Yam*, 9.I.1974, 30 spm. (HUJ); 1974, beach drift, 1 spm. (HUJ). *Bardawil Lagoon* (no locality indicated), 2.II.1970, 8 spm. (NS 12804).

Frequency:

Not uncommon, probably often overlooked due to small size (up to 3 mm).

Distribution:

- 1) *Mediterranean coast of Israel*: Mikhmoret, intertidal zone, among algae.
- 2) *Suez Canal*: Lake Timsah, Great and Little Bitter Lakes, (MOAZZO, 1939 : 184; BARASH and DANIN, 1973 : 354).
- 3) *Indo Pacific*: Gulf of Suez (MOAZZO, 1939 : 184); Gulf of Aqaba (LAMY, 1938 : 73); Red Sea, Aden (TOMLIN, 1927 : 297); Madagascar (DAUTZENBERG, 1929 : 293); Persian Gulf (BIGGS, 1973 : 360); Gulf of Oman, India - Bombay (MELVILL and STANDEN, 1901 : 371); Mauritius (VIADER, 1937 : 46); Japan, Korea, China (HABE, 1970 : 40).

Notes

1) Family Dialidae: « This group of cerithiaceans is ill-defined and little is known on the habits or anatomy of the animals. The species reported here are included in the family more as a matter of convenience than as indicating relationships. They have in common small size (from 2 mm to about 7 mm in length) and a complete aperture which distinguishes them from *Bittium* and other members of the Cerithiidae. Differences in protoconches may, however, belie different phylogenies ». (KAY, 1979 : 114).

2) MIENIS (1980 : 280) stated that the specimens of the Indo Pacific *Diala semistriata* (PHILIPPI, 1849) found in the Bardawil Lagoon agree rather well with specimens of *Diala varia* A. ADAMS, 1861 from Japan. *Diala varia* may therefore be considered as a junior synonym of *Diala semistriata* (PHILIPPI). The latter name is however preoccupied by *Diala semistriata* (DESHAYES, 1833), a fossil form from the Eocene period of France. The correct name for the Indo Pacific *Diala semistriata* which has migrated into the Mediterranean would therefore be *Diala varia* A. ADAMS, 1861.

MOAZZO (1939 : 184, 185) also considered *Diala varia* a synonym of *Diala semistriata*.

BIVALVIA
Family Mytilidae

Genus *Brachidontes*, SWAINSON, 1840

Brachidontes variabilis (KRAUSS, 1848) (Table I, Fig. 4) - Length 26 mm.

Mytilus variabilis KRAUSS, 1848 : 25, Pl. 2, fig. 5

Brachidontes variabilis (KRAUSS); DI GERONIMO, 1971 : 847, 1 text fig.

Mytilus pharaonis FISCHER, 1865; FISCHER, 1870 : 169

Bardawil Lagoon Records: BARASH and DANIN, 1971 : 100; 1973 : 333, fig. 18. POR, 1978 : 38.

Material:

Boaz I, 16.XII.1971, 1 valve (BFS). *Haparsa Is.*, 15.IV.1974, 19 spm. (BFS 304); 10.VII.1974, 1 valve (BFS 265); 15.IX.1974, 19 spm. (BFS 303). *Matiblis*, 1.IV.1974, 21 spm., 5 valves (NS 16788), 16.VII.1974, 16 spm. (BFS 263); 6.VIII.1974, 1 spm. (BFS 279); 17.XII.1974, 2 valves (HUJ); 9.II.1977, 1 valve (HUJ). *Lashon* I, 9.IX.1969, 50 spm., in clusters, (SLML 3211); 16.VII.1974, 6 valves (BFS 267, BFS 269), 6.VIII.1974, 2 spm. (BFS 283, BFS 284); 21.VIII.1974, 35 spm. (BFS 291, BFS 292); 3.IX.1974, 3 spm. (BFS 302); 15.IX.1974, 1 spm., 2 valves (BFS 307, BFS 309); 31.X.1974, 4 valves (HUJ); 12.XI.1974, 1 valve (HUJ). *Lashon* II, 11.VI.1974, 1 spm., 1 valve. *Rumia*, 25.XI.1974, 10 valves (HUJ). *Bardawil Lagoon* (localities not indicated), 1974, beach drift, 40 valves (HUJ); 1976, beach drift, 1 valve (HUJ).

Frequency:

Common, mostly in clusters, attached by byssus to hard substrates.

Distribution:

1) *Mediterranean coasts of Sinai and Israel*: from Rafah to Rosh Haniqra.

2) *Suez Canal*: mostly distributed in the Canal proper and in the Great and Little Bitter Lakes and Lake Timsah; from Ismailia to Port Said it becomes less abundant than in other parts of the Canal (MOAZZO, 1939 : 44, 262; BARASH and DANIN, 1973 : 359).

3) *Further distribution*: Indo Pacific: Gulfs of Suez and Aqaba, Red Sea, Aden (STURANY, 1899 : 40); South Africa - Natal (KRAUSS, 1848 : 26); Madagascar, Seychelles (LAMY, 1936 : 178); Mauritius (VIADER, 1937 : 60). India (MELVILL and STANDEN, 1906 : 799); Solomon Is. (DAUTZENBERG, 1910 : 30); New Caledonia, Australia (LAMY, 1936 : 178). Eastern Mediterranean: Egypt (PALLARY, 1912 : 156); Lebanon (GRUVEL and MOAZZO, 1931 : 450); Turkey - Alanya (SAFRIEL, GILBOA, FELSENBURG, 1980 : 41). Western Mediterranean: Sicily (DI GERONIMO, 1971 : 849); Ionian Sea, Calabria (ZANCA, 1976 : 161).

Family Cardiidae

Genus *Cerastoderma* POLI, 1795

Cerastoderma glaucum (BRUGUIÈRE, 1789) (Table II, Figs. 5-8)

Cardium glaucum BRUGUIÈRE, 1789; FISCHER-PIETTE, 1977 : 96

Cerastoderma glaucum (BRUGUIÈRE); NORDSIECK, 1969 : 101, Pl. XV, fig. 55.20

Bardawil Lagoon Records: BARASH and DANIN, 1971 : 100; POR, 1978 : 38.

Material:

Boaz I, VII. 1968, 2 valves (SFRS); 16.XII.1969, fragments of valves from the stomach of *Sparus auratus* (BFS); 2.II.1970, 50 spm., 110 valves (BFS); 11.VI. 1974, 1 spm., 32 valves (BFS 242); 2.VII.1974, 7 valves (BFS 252); 3.IX.1974, 5 spm., 23 valves (BFS 293, BFS 294). *Boaz* II, 12.VI.1974, 1 valve (BFS 246); 5.VIII.1974, 2 valves (BFS 275, BFS 276); 30.XI.1974, beach drift, over 100 valves (HUJ). *Haparsa Is.*, 15.IV.1974, 6 valves (BFS 304); 12.VI.1974, 10 valves (BFS 240), 10.VII. 1974, 2 valves (BFS 265); 6.VIII.1974, 7 valves (BFS 280); 15.IX.1974, 21 valves (BFS 303); 12.XI.1974, 1 valve (HUJ); 17.XII.1974, 24 valves (HUJ). *Matiblis*, 11. VI.1974, 31 valves (BFS 264); 16.VII.1974, 19 valves (BFS 263); 3.VIII.1974, 18 valves (BFS 254); 6.VIII.1974, 12 valves (BFS 279); 3.IX.1974, 7 valves (BFS 298); 25.XI.1974, 18 valves (HUJ); 17.XII.1974, 27 valves (HUJ); 9.II.1977, beach drift, 5 valves (HUJ). *Lashon* I, 9.IX.1969, about 500 spm., 21 valves (SLML 3240); 11. VI.1974, 6 valves (BFS 244); 12.VI.1974, 2 valves (BFS 247); 16.VII.1974, 1 spm., 8 valves (BFS 267, BFS 269); 6.VIII.1974, 6 valves (BFS 283, BFS 284); 21.VIII. 1974, 5 spm., 16 valves (BFS 291, BFS 292); 3.IX.1974, 4 spm. (BFS 301, BFS 302); 15.IX.1974, 4 spm., 4 valves (BFS 309, BFS 310); 31.X.1974, 13 valves (HUJ); 12. XI.1974, 3 valves (HUJ); 15.XII.1974, 7 valves (HUJ); 17.XII.1974, 8 valves (HUJ). *Lashon* II, 10.IX.1969, 8 spm. (SLML 3234); 2.IV.1974, 28 spm., 254 valves (BFS); 11.VI.1977, 2 spm., 12 valves (BFS 243); 13.IX.1974, 4 valves (BFS 294); 15.IX.1974, 1 spm., 11 valves (BFS 307, BFS 308); 10.X.1974, 17 valves (HUJ); 11.X.1974, 2 spm., 3 valves (BFS 300); 31.X.1974, 14 valves (HUJ); 25.XI.1974, 9 valves (HUJ); 17.XII.1974, 20 valves (HUJ). *Rumia*, 2.VI.1974, 3 valves (BFS 235); 2.VII.1974, 6 valves (BFS 249); 5.VIII.1974, 18 valves (BFS 272); 16.VIII.1974, 15 valves (BFS 271); 10.X.1974, 12 valves (HUJ); 25.XI.1974, 115 valves (HUJ); 6.XII.1974, 10 valves (HUJ). *Bardawil Lagoon*, (localities not indicated), 1974, 60 valves (HUJ); 1976, beach drift, 64 valves (HUJ).

Frequency:

Very common.

Distribution:

1) *Mediterranean coasts of Sinai and Israel:* Widely distributed along the coasts of Sinai and Israel from El Arish to Akhziv.

2) *Suez Canal:* *Cerastoderma glaucum* is commonly found in the Manzala Lake, Lake Timsah, the Great and Little Bitter Lakes, in the salt marshes near Port Said and in the Canal proper (MOAZZO, 1939 : 69, 70; BARASH and DANIN, 1973 : 362).

3) *Further distribution:* Black Sea (GROSSU and CARAUSSU, 1959 : 217); Sea of Marmara (OBERLING, 1969-1971 : 191). Eastern Mediterranean: Egypt (PALLARY, 1912 : 164); Lebanon-Syria (GRUVEL and MOAZZO, 1931 : 449). Cyprus (DEMETROPOULOS, 1971 : 21); Aegean Sea (FORBES, 1844 : 144). Western Mediterranean: Ionian Sea - Taranto (PARENZAN, 1961 : 43); Adriatic Sea, Sicily, West Italy, Corsica,

Sardinia, South France, East Spain, Balearic Is., Algeria, Tunisia (CARUS, 1893 : 112); Malta (MICALLEF and EVANS, 1968 : 165); Morocco - Melilla (PALLARY, 1920 : 86); Cyrenaica (MONTEROSATO, 1923 : 4). Eastern Atlantic seas: Baltic Sea (RUSSELL, 1971 : 232); Britain (BOWDEN and HEPPELL, 1968 : 268). Indo Pacific: Gulf of Suez (FISCHER-PIETTE, 1977 : 97).

Notes

Cardium (Cerastoderma) glaucum was formerly considered as a synonym of *Cardium (Cerastoderma) edule* (BDD, 1892 : 284).

The subgenus *Cerastoderma* POLI of *Cardium* was elevated to generic level (TEBBLE, 1966).

The many named varieties generally grouped under *Cerastoderma edule* L., were shown by MARS (1951) to be referable to two distinct species: true *C. edule* and to *C. glaucum* (see BOWDEN and HEPPELL, 1968 : 268).

Cerastoderma edule and *C. glaucum* have been known by the same name (*Cardium edule*) for many years.

The name *Cerastoderma lamarckii* (REEVE) which was used by TEBBLE (1966) and others, has been equated with *C. glaucum* (RUSSELL, 1971 : 225).

Family Mactridae

Genus *Mactra* LINNAEUS, 1767

Mactra olorina PHILIPPI, 1846; DAUTZENBERG, 1929 : 410 (616) (Table I, Fig. 9) · Length 50 mm.

Bardawil Lagoon Records: BARASH and DANIN, 1973 : 342; POR, 1978 : 38

Material:

Boaz I, 2.VII. 1974, 4 valves (BFS 252). *Matiblis*, 6.VII.1974, 2 valves (BFS 279). *Lashon* I, 3. VI.1974, 1 spm., 27 valves (BFS 283); 12.VI.1974, 4 valves (BFS 247); 16.VII.1974, 8 valves (BFS 267, BFS 270); 6.VIII.1974, 3 spm., 48 valves (BFS 284); 21.VIII.1974, 39 valves (BFS 291, BFS 292); 3.IX.1974, 2 valves (BFS 301); 15.IX.1974, 8 valves (BFS 309, BFS 310); 31.X.1974, 4 valves (HUJ); 12.XI.1974, 1 valve (HUJ); 15.XII.1974, 9 valves (HUJ); 17.XII.1974, 10 valves (HUJ). *Lashon* II, 3.IX.1974, 1 spm., 38 valves (BFS 294); 15.IX.1974, 1 spm., 25 valves (BFS 307; BFS 308); 10.X.1974, 27 valves (HUJ); 11.X.1974, 53 spm., 10 valves (BFS 300); 31.X.1974, 92 valves (HUJ); 25.XI.1974, 26 valves (HUJ). *Rumia*, 2.VI.1974, 5 valves (BFS 235); 16.VIII.1974, 4 valves (BFS 271); 25.XI.1974, 5 valves (HUJ). *Nabal Yam*, 2.IV.1974, 22 spm., 111 valves (NS 16789). *Bardawil Lagoon*, (no localities indicated), 9.IX.1969, 1 spm. (SLML 3231); 10.IX.1969, 88 spm. (SLML 3241); 1976, beach drift, 1 valve (HUJ).

Frequency:

Common.

Distribution:

1) Eastern Mediterranean coasts: Sinai and Israel - Rafah, Tel Aviv (Tel Barukh); Lebanon-Beirut (GRUVEL and MOAZZO, 1931 : 452).

2) *Suez Canal*: *Mactra olorina* is common in Lake Timsah, in the Great and Little Bitter Lakes and in the Canal proper, becoming rare near Port Said (MOAZZO, 1939 : 104; BARASH and DANIN, 1973 : 365).

3) *Further distribution*: Indo Pacific: Gulf of Suez (MOAZZO, 1939 : 104); Gulf of Aqaba, Red Sea (STURANY, 1899 : 38); Madagascar (DAUTZENBERG, 1929 : 616); Persian Gulf (MELVILL, 1928 : 116); Indonesia-Java (REGTEREN-ALTEA 1945 : 151).

General Remarks

The species resident in the Bardawil Lagoon are benthos dwellers.

The sandy and muddly grounds of the Bardawil Lagoon provide suitable substrates for the *Pirenella* species that crawl on the bottom surface, as well as for the shallow burrowing *Cerastoderma glaucum* and *Mactra olorina*.

The typical hard bottom (rocks and stones) dwellers as the *Brachidontes variabilis*, lack their natural substrate in the Lagoon. They fasten their byssus to solid structures, such as piers, poles etc. No observations were made in the Lagoon concerning the bottom appropriate for *Cerithium scabridum*, which is usually confined to rocky shores, and for *Diala varia*, found along Israeli coasts among algae.

The high average temperature, characteristic of the water in the Lagoon, accelerates the decomposition of dead plants on the bottom, and small particles of detritus are abundant in the water. The strong illumination in the area of Bardawil is an influential factor for the primary production of the plants in the Lagoon: the angiosperm *Ruppia*, the filamentous algae (*Cladophora* spp.) and the phytoplankton (see KIMOR, 1975; KIMOR and BERDUGO, 1969).

The phytoplankton is characterised by the abundance of dinoflagellates and diatoms. The dinoflagellates are represented by several species, by far the most common being *Ceratium furca* and *C. fusus*. Among the Diatomacea are three *Synedra* species, and the foremost being *Campylostylus striatus*.

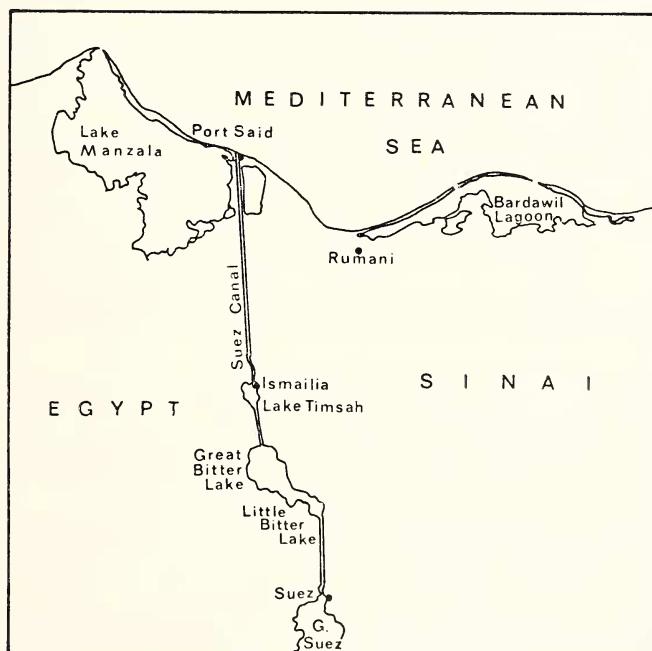
The zooplankton consists mainly of Protozoa and Crustacea. The common protozoan species belong to *Tintinnida*. The Crustacea are represented only by Entomostraca: some species of *Coopoda*, one species of *Cladocera-Bosmina coregoni maritima*. Larvae of cirripedes occur in the plankton.

The Lagoon is rich in food for the molluscs living there. The Cerithioidea (*Pirenella conica*, *Diala varia*, *Cerithium scabridum*) feed upon algae and detritus. The bivalves subsist on the food particles suspended in the water.

The number of molluscan species living permanently in the Lagoon is very small (6) in comparison with the hundreds that live in the open sea nearby.

The molluscs inhabiting the Lagoon are euryhaline, tolerant to fluctuations in the salinity of the water. Apart from Bardawil they occur in the adjoining areas in sites of changing salinities: eastwards in the intertidal zone along the Mediterranean coasts of Sinai and Israel and the salt water bodies close to them, and westwards in the water system of the Isthmus of Suez: the Bitter Lakes, Lake Timsah, Lake Manzala and the Canal proper. The Bardawil Lagoon is considered to be a part of this water system, being connected with Lake Manzala through the periodically flooded swamps of the Rumani area (Map 3).

The Bardawil Lagoon lies at a relatively short distance (45 km) from the northern outlet of the Suez Canal, which may be regarded as a starting point for the penetration of Indo Pacific species into the Mediterranean. To date 32 Indo Pacific species have been recorded as living permanently along the Mediterranean coasts of Israel and Sinai. Of these, only 4 species are recognised as residents in the Lagoon: *Diala varia*, *Cerithium scabridum*, *Brachidontes variabilis* and *Mactra olorina*. The Lagoon has remained blocked against the intrusion of other Indo Pacific immigrants, despite its closeness to the Suez Canal and its free connection with the Mediterranean.



Map 3 - The water system of the Isthmus of Suez

The taxonomic diversity of the Mollusca living in the Bardawil Lagoon is very limited. At the level of classes, only species of Gastropoda and Bivalvia hold ground there. Of the Gastropoda only the Cerithioidea are represented. Somewhat more heterogeneous is the composition of the Bivalvia. The Pteriomorpha are represented by the superfamily Mytiloidea; the Heterodontia by Cardioidea and Mactroidea.

The Molluscan species living in the Lagoon are very variable in form. The differences in size, sculpture, colour etc. among the individuals of *Pirenella conica* (= *P. cailliaudi*) were noted by PALLARY, (1912 : 112), TOMLIN, (1927 : 296), JOUSSEAUME, (1930 : 294), BARASH and DANIN, (1977 : 89).

MIENIS (1976 : 30) pointed out that *Diala varia* A. ADAMS = *Diala semistriata* (PHILIPPI) is polymorphic and polychromic and contains different forms.

JOUSSEAUME (1930 : 279) stated that *Cerithium scabridum* is extremely variable in size, height, sculpture and colouration.

KRAUSS (1848 : 25), the first to describe *Brachidontes variabilis*, noted that this species is very variable.

MOAZZO (1939 : 104) found in the Suez Canal specimens of *Mactra isthmia* JOUSSEAUME, 1888 similar to *Mactra olorina*. The colour, however, and the lightness of the shell are reminiscent of *Mactra corallina* from the Mediterranean. *M. isthmia* probably constitutes a kind of transition from *M. olorina* to *M. corallina*.

The most variable is *Cerastoderma glaucum*. This species deserves particular notice because of its extreme aptitude for life in water of various salinities. It is a very polymorphic species. Over 20 varieties are enumerated by NORDSIECK (1969 : 101), mostly Mediterranean, and of them the following four are represented along the Mediterranean coasts of Israel and Sinai, as well as in the Bardawil Lagoon [identified by G.H. PETERSEN, Zoological Museum, Copenhagen and indicated in his report (1976)].

Cerastoderma glaucum glaucum (BRUGUIÈRE, 1789) (Table II, fig. 5)
L. 24 x H. 20 mm

= var. *typica* = ? var. *quadrata* B.D.D.

B.D.D., 1892 : 296, Pl. 47, figs. 14-17; MARS, 1951 : 13, Pl. III, figs. 16-18; PARENZAN, 1974 : 196, fig. 225i.

Remark: B.D.D. (1892 : 296) suggested that «varieté *quadrata* pouvait se rapporter au type de *C. glaucum*» (MARS, 1951 : 16).

Cerastoderma glaucum crassum (COEN, 1915) (Table II, Fig. 6)

L. 29 x H. 26 mm

MARS, 1951 : 17, Pl. II, figs. 16, 17; NORDSIECK, 1969 : 101.

Cerastoderma glaucum rectidens (COEN, 1915) (Table II, Fig. 7)

L. 17 x H. 15 mm

MARS, 1951 : 18, Pl. II, figs. 18-20; NORDSIECK, 1969 : 101, Pl. XV, fig. 56.33; PARENZAN, 1974 : 197, fig. 225 k.

Cerastoderma glaucum umbonatum (WOOD, 1850) (Table II, Fig. 8)

L. 21 x H. 20 mm

B.D.D., 1892 : 295, Pl. 47, fig. 12; MARS, 1951 : 20, Pl. III, fig. 19; NORDSIECK, 1969 : 102, Pl. XV, fig. 55.36; PARENZAN, 1974 : 197, fig. 225 n.

Remark: According to PETERSEN (1976) the shells of var. *umbonata* of Israel are probably subfossil and may not be accepted as part of the living fauna of Israel.

The variations of *Cardium edule* (of *Cerastoderma edule*) and of *C. glaucum* present a subject of great interest. These molluscs provide an ample opportunity to observe modifications which may be caused to the shell (shape, number of ribs, colour, thickness of the valves) according to the conditions in the environment - salinity, temperature, character of bottom, wave action. (B.D.D., 1892; PURCHON, 1939; RUSSELL and PETERSEN, 1973; PARENZAN, 1974). However, the material of *C. glaucum* collected up to now in the Bardawil Lagoon contains many empty shells, with some so worn that they are either transported to the Lagoon by waves or are perhaps subfossil. The investigation of the effect of such a peculiar environment as Bardawil Lagoon upon the shells of *Cerastoderma glaucum* living there remains, for the time being, beyond the scope of this work.

Remnants of shells and the soft body of molluscs are often found in the stomach of molluscivorous fishes captured in the Lagoon. MIE-NIS (1977) acknowledged the finding of *Pirenella conica*, *Cerithium scabridum*, *Brachidontes variabilis* and *Cerastoderma glaucum* in the stomach of the fish *Dicentrarchus labrax* (L.). BARASH and DANIN (1971) reported the finding of the same molluscs as well as of *Modiolus glaberrimus*, *Modiolus arcuatus*, *Venerupis aurea*, *Mactra corallina* in the stomach of the fish *Sparus auratus*. The latter four species of bivalves were not reported as living in the Lagoon. The fishes, the stomachs of which contained the remnants of molluscs, might have arrived in the Lagoon after preying upon the molluscs in the nearby open sea.

Empty shells of molluscan species not belonging to the constant population in the Lagoon are found more or less frequently there. These shells have obviously drifted into the Lagoon with the waves from the open sea (see following list).

Thus 57 species are encountered occasionally in the Lagoon, being found there as dead shells. Of these, a few were represented by more than 10 shells (or valves), i.e. *Cerithium vulgatum* - 20, *Trunculariopsis trunculus* - 32, *Cyclope neritea* - 16, *Scapharca natalensis* - 38, *Loripes lacteus* - 19, *Venerupis aurea* - 20, *Mactra corallina* - 12, *Macoma cumana* - 17, *Donax trunculus* - 53 and *Scrobicularia cottardi* - 20.

List of Mollusca occurring occasionally in the Bardawil Lagoon

Species	Number of shells	Region
Gastropoda		
<i>Cingula vitrea</i> (MONTAGU)	1	Mediterranean
<i>Rissoa lineolata</i> MICHAUD	2	Mediterranean
<i>Rissoa</i> spp.	7	—
<i>Dablakia</i> cf. <i>leilae</i> BIGGS	11	Indo Pacific
<i>Scaliola</i> cf. <i>elata</i> ISSEL	1	Indo Pacific
<i>Bittium reticulatum</i> (DA COSTA)	1	Mediterranean
<i>Cerithium vulgatum</i> BRUGUIÈRE	20	Mediterranean
<i>Neverita josephinia</i> RISSO	6	Mediterranean
<i>Trunculariopsis trunculus</i> (LINNAEUS)	32	Mediterranean
<i>Murex brandaris</i> LINNAEUS	2	Mediterranean
<i>Thais carinifera</i> (LAMARCK)	2	Indo Pacific
<i>Cyclope neritea</i> (LINNAEUS)	16	Mediterranean
<i>Hinia reticulata</i> (LINNAEUS)	2	Mediterranean
<i>Hinia incrassata</i> (STRÖM) s. sp. <i>jousseamei</i> (LOCARD)	1	Mediterranean
<i>Hinia pymgaea</i> (LAMARCK)	1	Mediterranean
<i>Nassarius arcularius</i> (LINNAEUS) s. sp. <i>plicatus</i> (RÖDING)	3	Indo Pacific
<i>Vasum turbinellus</i> (LINNAEUS)	1	Indo Pacific
<i>Chrysallida</i> sp.	1	—
<i>Atys blainvilliana</i> (RECLUZ)	1	Mediterranean
<i>Haminea hydatis</i> (LINNAEUS)	1	Mediterranean
<i>Retusa</i> spp.	2	—
<i>Ventomnestia girardi</i> (AUDOUIN)	7	Indo Pacific
Scaphopoda		
<i>Dentalium dentalis</i> LINNAEUS	1	Mediterranean
Bivalvia		
<i>Scapharca natalensis</i> (KRAUSS)	38	Indo Pacific
<i>Striarca lactea</i> (LINNAEUS)	1	Mediterranean
<i>Mytilaster minimus</i> (POLI)	1	Mediterranean
<i>Modiolus glaberimus</i> (DUNKER)	3	Indo Pacific
<i>Modiolus arcuatus</i> HANLEY	8	Indo Pacific
<i>Chlamys varia</i> (LINNAEUS)	1	Mediterranean
<i>Lima lima</i> (LINNAEUS)	1	Mediterranean and Indo Pacific
<i>Anomia ephippium</i> LINNAEUS	6	Mediterranean
<i>Ostrea</i> spp.	26	—
<i>Glans trapezia</i> (LINNAEUS)	1	Mediterranean
<i>Loripes lacteus</i> (LINNAEUS)	19	Mediterranean
<i>Divaricella angulifera</i> (VON MARTENS)	1	Indo Pacific
<i>Diplodonta rotundata</i> (MONTAGU)	1	Mediterranean
<i>Dosinia lupinus</i> (LINNAEUS)	2	Mediterranean
<i>Venerupis aurea</i> (GMELIN)	20	Mediterranean
<i>Irus irus</i> (LINNAEUS)	2	Mediterranean
<i>Chamelea gallina</i> (LINNAEUS)	9	Mediterranean
<i>Clausinella fasciata</i> (DA COSTA)	4	Mediterranean
<i>Petricola lithophaga</i> (RETZIUS)	1	Mediterranean

<i>Macra corallina</i> (LINNAEUS)	12	Mediterranean
<i>Spisula subtruncata</i> (DA COSTA)	3	Mediterranean
<i>Angulus incarnatus</i> (LINNAEUS)	1	Mediterranean
<i>Angulus planatus</i> (LINNAEUS)	2	Mediterranean
<i>Angulus valtonis</i> (HANLEY)	6	Indo Pacific
<i>Macoma cumana</i> (O.G. COSTA)	17	Mediterranean
<i>Donax trunculus</i> LINNAEUS	53	Mediterranean
<i>Donax semistriatus</i> POLI	3	Mediterranean
<i>Donax venustus</i> POLI	2	Mediterranean
<i>Soletellina rubra</i> SCHRÖTER	2	Indo Pacific
<i>Soletellina subradiata</i> (REEVE)	1	Indo Pacific
<i>Abra alba</i> (WOOD)	3	Mediterranean
<i>Abra ovata</i> (PHILIPPI)	10	Mediterranean
<i>Scrobicularia cottardi</i> (PAYRAUDEAU)	20	Mediterranean
<i>Barnea candida</i> (LINNAEUS)	1	Mediterranean

Acknowledgement

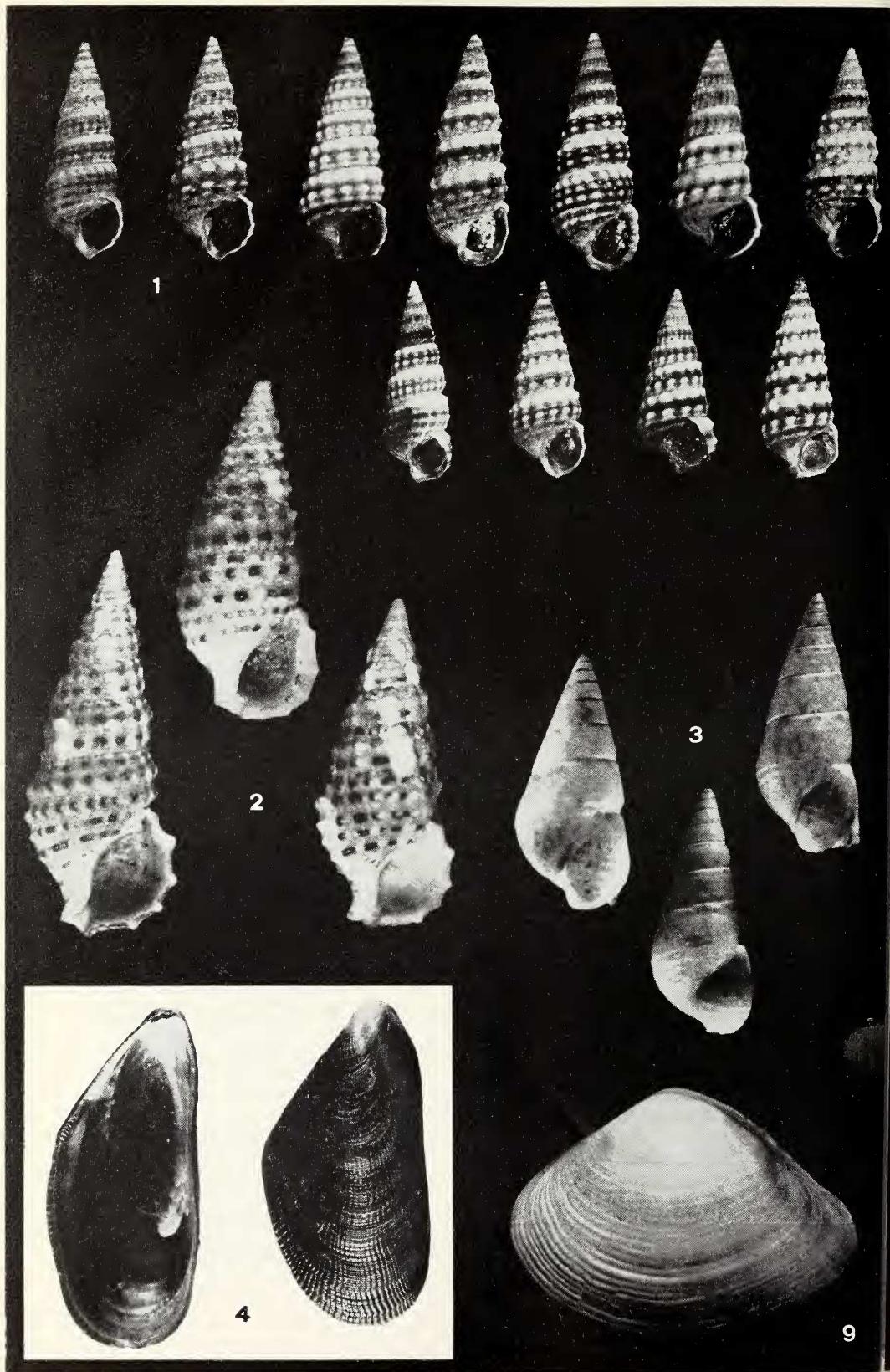
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TABLE I

Fig. 1 - Variations of *Pirenella conica* (BLAINVILLE, 1826); height 12.5 mm.
 Fig. 2 - *Cerithium scabridum* PHILIPPI, 1849; height 18 mm.
 Fig. 3 - *Diala varia* A. ADAMS, 1861 = *Diala semistriata* (PHILIPPI, 1849); height up to 3 mm.
 Fig. 4 - *Brachidontes variabilis* (KRAUSS, 1848); length 21 mm, width 11 mm.
 Fig. 9 - *Mactra olorina* PHILIPPI, 1846; length 30 mm, height 23 mm.

TABLE II

Fig. 5 - *Cerastoderma glaucum glaucum* (BRUGUIÈRE, 1789); length 24 mm, height 21 mm.
 Fig. 6 - *Cerastoderma glaucum crassum* (COEN, 1915); length 29 mm, height 26 mm.
 Fig. 7 - *Cerastoderma glaucum rectidens* (COEN, 1915); length 17 mm, height 14 mm.
 Fig. 8 - *Cerastoderma glaucum umberatum* (WOOD, 1850); length 21 mm, height 20 mm.





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